International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 2, Apr 2018, 113-120

TRANS STELLAR
• Journal Publications • Research Consultancy

INFLUENCE OF ADDITION OF SILICON ON MECHANICAL PROPERTIES OF ALUMINIUM – ZINC ALLOY

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ABSTRACT

In this investigation, the experiment was conducted to analyze the mechanical properties such as Yield Strength, Ultimate Tensile Strength, Hardness on Al-Zn alloy of different composition Specimen 1 (89.4%Al4%Zn1%Mg0.6%Mn) , specimen 2 (86.4%Al4%Zn1%Mg0.6%Mn), specimen 3 (84.4%Al4%Zn1%Mg0.6%Mn) by the addition of 5%, 8% and 10% silicon. It was found that the mechanical properties were improved by the addition of silicon. It was noted that the maximum yield strength 103 N/mm2, Ultimate Tensile Strength of 116 N/mm2 and Hardness of 60.9BHN were obtained for the addition of 10% silicon to aluminium-Zinc alloy. Also, SEM (Scanning Electron Microscope) analysis was taken and presence of silicon content was analyzed.

KEYWORDS: Aluminium-zinc alloy, silicon, Yield Strength , Ultimate Tensile Strength & Hardness

Received: Jan 16, 2017; **Accepted:** Feb 05, 2018; **Published:** Feb 26, 2018; **Paper Id.:** IJMPERDAPR201812

Original Article

INTRODUCTION

Aluminium alloys are very important in many industrial applications, because of their light weight and good mechanical properties. Aluminium alloys are sought as a conventional material in the field of aerospace, automobile and marine application due to their valuable mechanical properties. The usage of aluminium lowers the density, coefficient of thermal expansion, improves the corrosion and wear resistance as compared to the conventional counterparts.

Narendra Kumar et al.[I] studied the effects of heat treatment on the mechanical properties Al-Si (ADC12) alloy. The mechanical properties such as tensile strength, compressive strength, hardness and impact strength of the composite structures subjected to heat treatment were studied in order to achieve the maximum properties. Microstructural examination was carried out to observe the aging effect. X-ray diffraction of the alloy in as cast and heat treated condition was done to distinguish the phases present in the material. The fracture surface study was performed to identify clearly the type of fracture taking place in the alloy under the action of load. It is observed that there is a significant improvement in the properties of the alloy due to heat treatment as compared to the as cast alloy. The microstructural study reveals the dendrites of aluminium with an arm spacing in the range of 25 microns, whereas the eutectic silicon solidifies in the inter-dendretic region surrounding the dendrites. On heat treatment action the plate shaped eutectic silicon is being fragmented into spherical shape. X-ray diffraction analysis, highlights and marks the major peaks of aluminum and minor peaks of intermetallic phases such as $CuAl_2$, Al_2CuMg and Mg_2Si in cast as well as in heat treated condition. The tensile fracture surface study shows the fracture is taking place by inter- granular manner (crack propagation along the grain boundary)

and morphology of dendrites in the fracture surface. In recent years, the demand for aluminium alloys in automotive industries is rapidly growing. It is used to make cylinder blocks and crank cases due to its light weight, which also assists in reduction of fuel consumption. Aluminium alloyed with copper, magnesium, manganese, silicon, and zinc shows a great improvement in properties of high tensile strength, low density, durability and machinability. Surfaces of aluminium alloys have a brilliant luster, especially in dry environment due to the formation of a shielding layer of aluminium oxide. Aluminium alloys that are categorized into 4xxx, 5xxx and 6xxx series, that consists of additives of Mg, Cu and Si are now replacing steel panels in various automobile industries. Due to such reasons, these alloys were subjected to several scientific studies in the past few years [II]. In an effort to improve the tensile strength of aluminum, silicon (Al-Si) alloys, investigation of the influence of Si concentration and heat-treatment at 453° K on the susceptibility of Al-Si alloys to inter granular corrosion was carried out. The results showed that susceptibility to inter-granular corrosion, increased with an increase in Si concentration. It also initially increased with heat-treatment at 453° K, but then decreased with long-term heat-treatment at 453° K. The addition of Mg and Mn promoted precipitation and reduced the susceptibility of the Al-Si alloys to inter granular corrosion. With longer heat-treatment at 453° K, large Si precipitates were observed in the grains and at the grain boundaries, which reduced the susceptibility to inter granular corrosion whereas short-term heat-treatment at 453° K formed a continuous Si-depleted layer along the grain boundaries, which increased the susceptibility to inter granular corrosion. It is suggested that the susceptibility to inter granular corrosion depends on the addition of Mg and Mn [III].

Nikanorova et al.[IV] conducted an experiment on Structural and mechanical properties of Al–Si alloys. Samples of various compositions from 11.5 to 35 wt.% Si were obtained by rapidly cooling levitated melts. The measurements revealed a linear concentration and depends on density and Young's modulus. The average temperature coefficient of Young's modulus at room temperature is around 500 ◦C and the yield point for bending both had maxima at about 20 wt.% Si. The temperature dependence hysteresis of Young's modulus had lowest at about 20 wt.% Si as well. Altering Young's modulus temperature coefficient and Young's modulus hysteresis as a function of the Si content are connected with the creation of the Guinier–Preston zones. The values of the yield point are explained by the plasticity of the components of the artistic structure, primary crystals and grain boundaries. The extreme of the concentration dependencies of the mechanical properties occurred in the fine-grained structure arose from coupled autistic-like growth. Solidification formed primary crystals of solid solution or primary Si crystals at other specific conditions.

Al-Si alloys are in demand owing to their high strength to weight ratio. The enhancement in properties is further observed when different elements are added. Al-Si alloy find their application mostly in automobile and aerospace engineering. Si nucleates as needle like structures when solidified. These needle structures when modified exhibit wear. The microstructure can be altered and mechanical properties can be improved when subjected to heat treatment. Also the typical alloying elements are copper, magnesium and nickel. The aim was to determine the effect of Si content on the microstructure and mechanical properties of hypo eutectic, eutectic and hypereutectic Al–Si piston alloys. The alloys of different content of Si namely 4, 6, 8, 10, 14 and 16 % are produced by gravity die casting route in an electric resistance furnace. The paper also stresses upon the role of heat treatment on the microstructure and hence the mechanical properties of the Al-Si piston alloy. Ultimate tensile strength and hardness has increased with increase in silicon content. The application of heat treatment resulted in a finer microstructure and a uniform distribution of the intermetallic compounds and it modifies the eutectic Si phase and hence improves the mechanical properties of the alloy[V]. Prasad[VI] noticed that the influence of microstructural changes brought about by T6 type heat treatment is primarily focused here.

The tensile strength and elongation of Zinc-37.5 mass% aluminium based alloys are studied. Test conditions include strain rate and temperature. It is observed that micro cracking tendency and thermal stability play a vital role in exerting an influence on mechanical properties. Alloys exhibit changes correspondingly with respect to test conditions.

Sutiarso et al.[VII] studied the influence of copper and silicon additions on the extrudability and mechanical properties of a series of aluminium alloys based on AA6111. Addition of cu in aluminium alloys showed beneficial results in increasing strength. A study has been made on additions of up to 0.7% by wt of Cu 0.33-0.56% by wt of si specifically for extrusion purposes. Results showed the addition of both decreased extrudability and also triggering the breakthrough force. Standard extrusion limit diagrams were constructed at specific pressure of 600 and 700 Mpa at temperatures 400°C and 500°C. Samples were press quenched (cold water) and aged at 170°C for 8 hours. The addition of cu remarkably increased the UTS. However, silicon did not have a significant effect. But when Silicon additions were treated at 565°C for 30 minutes and water quenched and aged with an increase in Silicon concentration did increase the tensile properties. Various researchers studied the aluminium alloy [VIII] and effect of silicon [IX,X] on mechanical properties.

EXPERIMENTAL PROCEDURE

Readily available aluminium and silicon are taken. An alloy is prepared with the designated composition and silicon content alone is varied in successive intervals in a specific % by weight and the individual properties of each sample are tested. Out of all the important properties, yield strength, ultimate strength and hardness number are considered. A graph is plotted keeping X-axis constant with silicon content in % by weight and altering the Y-axis respectively. Cylindrical specimens were cast using a sand mould for different compositions of the alloying elements. Microstructure analysis was carried out using SEM and samples were analyzed. Hardness testing was carried out using a Brinell hardness testing machine. The aluminium rods obtained from casting were machined using lathe so as to prepare the samples for tensile testing. Yield strength and tensile strength were found using a universal testing machine.

Specimen Preparation

In this process, the metal which has the highest melting temperature is firstly poured into the crucible and allowed to melt in the furnace. The metal which posses low melting temperature is allowed to melt in the last, because if it will allow to melt with metal which possess highest temperature then the low melting temperature metal will get burn. After pouring molten metal into the mould cavity allows solidifying into the mould cavity. Alloy specimens were heat treated in a programmable furnace for comparing the properties as cast and aged condition. There were three stages involved in the heat treatment. The specimens were heated to a temperature of 490 ± 5 ^{0}C for 8 hours until the alloy solute elements are completely dissolved in the Al solid solution. The solution treated specimens were rapidly cooled in to oil (at room temperature) to prevent the precipitation of the solute elements and to obtain a super saturated solid solution. To improve the strength and hardness of the material the specimens were reheated, to 135 ^{0}C /150 ^{0}C /175 ^{0}C /200 ^{0}C /230 ^{0}C for 6 hours each and then allowed to cool in air.

Figure 1: Casted Component (Specimen)

Mechanical Testing

The specimens were tested at room temperature for various tests. Mechanical properties such as Yield strength and ultimate tensile strength were evaluated on computerized Universal testing machine (INSTRON M/c, Model 5586) 400KN Capacity at a strain rate of 0.5 mm/min. Hardness and Impact strength were evaluated on the Analog Rockwell hardness tester (FIE makes, model VM 50).

Micro Structural Examination

Samples for micro structural characterization were polished according to standard metallographic procedures. Various steps involved during the process were polishing the specimens with different grade of emery papers and then finally with fine polishing alumina using polishing cloths. The samples were etched with Keller's reagent and observed in a SEM.

RESULTS AND DISCUSSIONS

Yield Strength

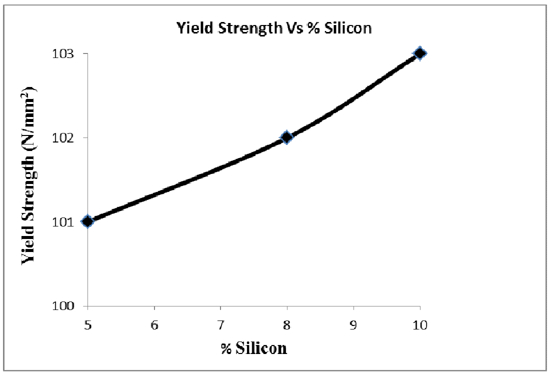


Figure 2: %Silicon Vs Yield Strength

The given figure 2 depicts the relationship between the % content of silicon in the aluminium alloy and the yield strength of the aluminium alloy along X and Y respectively. Yield strength or yield stress is defined as the stress at which the alloy(in this case aluminium with silicon content) begins to deform plastically. From the graph,the yield strength for the specimen1 was 101 N/mm^2. The yield strength is increased when the % content of silicon is increased. Then, when the silicon content is 8% by weight, the yield strength reaches a value of 102 N/mm^{2}and finally the graph reaches a peak of 103 N/mm^2 at 10% silicon content.

Ultimate Tensile Strength

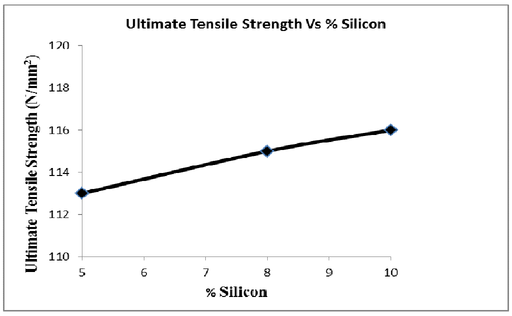


Figure 3: % Silicon Vs Ultimate Tensile Strength

The figure 3 shows the relation between % content of silicon in aluminium alloy and its effect on ultimate tensile strength against X-Y axis respectively. Ultimate tensile strength simply known as tensile strength/ ultimate strength is the capacity of a material (in this case aluminium alloy enriched with silicon) to withstand loads tending to elongate as opposed to compressive strength. The graph begins at 5% silicone content, giving the alloy an ultimate strength of 113 N/mm^2 and as the silicon content is raised to 8% by weight it spikes to 115 N/mm^2 and ultimately a peak of 116 N/mm^2 is obtained for10% silicon content.

Hardness

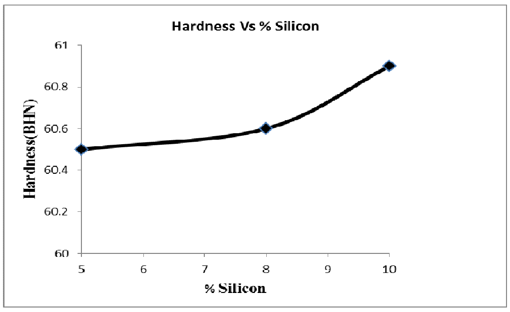
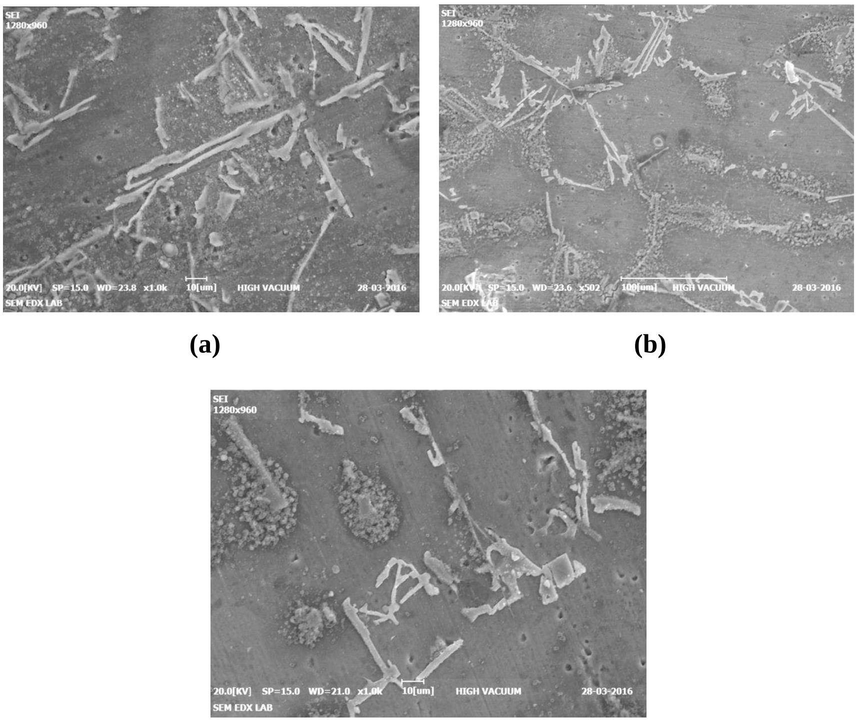


Figure 4: %Silicon Vs Hardness

This figure 4 clearly shows the change in hardness that occurs with change in % of silicon with silicon content along X and hardness number along Y respectively. Hardness is defined as the measure of resistance to localized plastic deformation induced either by mechanical indentation or abrasion. Here initially with 5% of silicon content in the aluminium alloy the hardness value is 60.5 BHN then as the silicon content is increased to 8% by weight, hardness becomes 60.6 BHN and when the Silicon content is gradually increased and finally reaches a value of 10% the hardness reaches a crown value of 60.9BHN.

SEM Analysis

SEM stands for scanning electron microscope. SEM microscope uses electron beam instead of light for image formation. The SEM has allowed researchers to examine a much bigger variety of specimens. The SEM has a large depth of field that allows the user to study much more specimens in focus at a time. The SEM of samples of aluminium + 4% zinc alloy with 5%, 8%, 10% of silicon was taken and the results were analyzed. The samples are taken and were scanned under scanning electron microscope for obtaining the respective images of the samples. The appropriate images of each sample were given below.



(a) **(b)**

(c)

Figure 5 (a, b, c): SEM Image for Specimen1, 2 & 3

The figure 5 a,b,c shows the SEM analysis image of specimen 1,2 &3. It is noted that the silicon content appears as sharp spike shaped grain structure. When the silicon content increases, the sharp spike shaped grain structure increases. Specimen 1 contains only 4% of silicon content which shows small sharp spike shape grain structure. Sharp spike shape, grain structure increased in size, because of increased silicon content. This is represented in figure 5 band 5c.

CONCLUSIONS

The mechanical properties were obtained for the addition of silicon content to aluminium-zinc alloy. The following conclusions were obtained for maximum value at 10% addition of silicon.

- Yield strength was 103 N/mm^2
- Ultimate tensile strength was 116 N/mm^2
- Hardness was 60.9 BHN

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